B-91 Fire Protection Analysis

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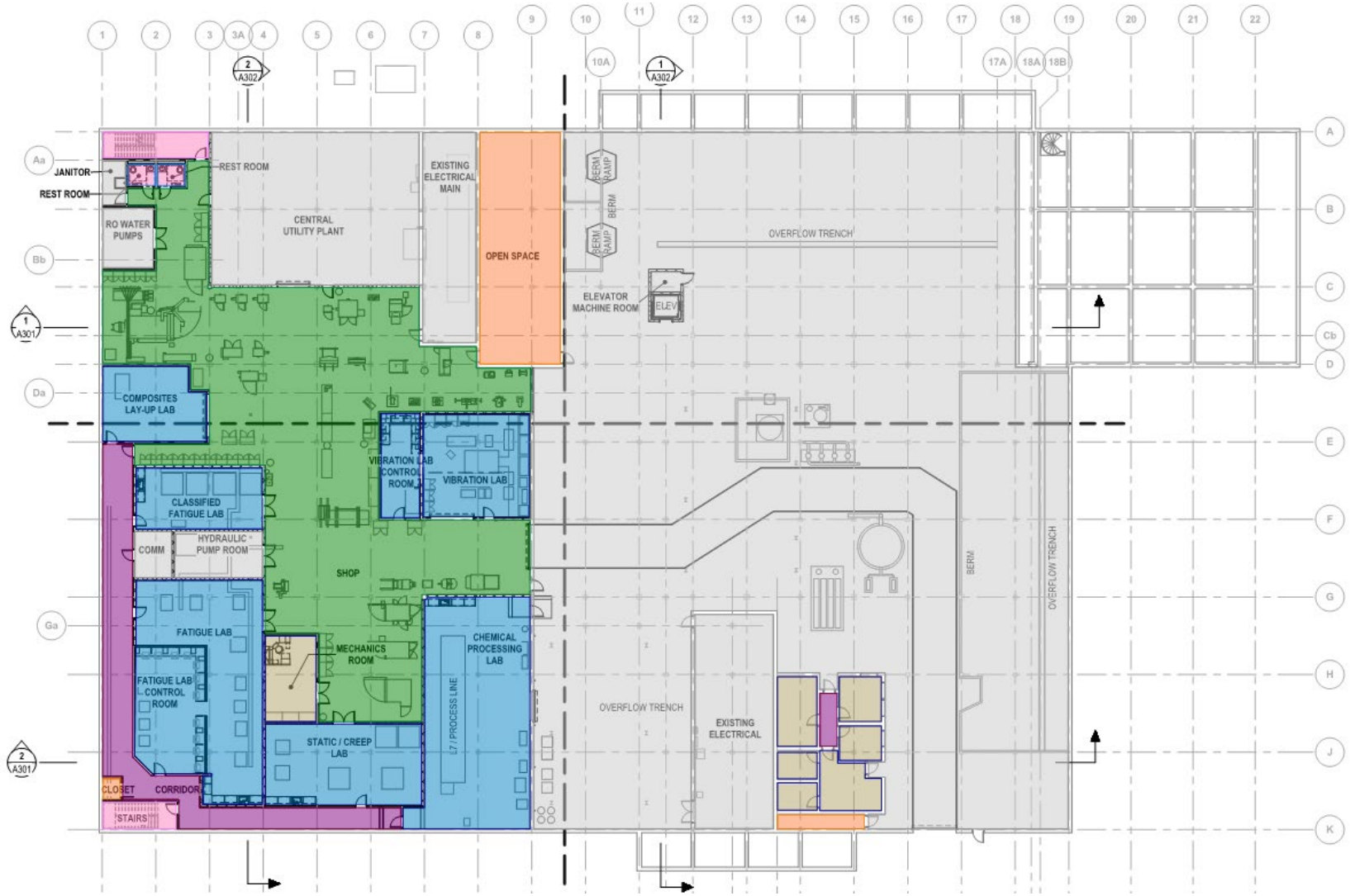
Basement Floorplan



Legend

- Office
- Service Spaces
- Storage S-2 Low Hazard Storage
- Laboratory
- Exit Access Corridors
- Restrooms
- Factory F-1

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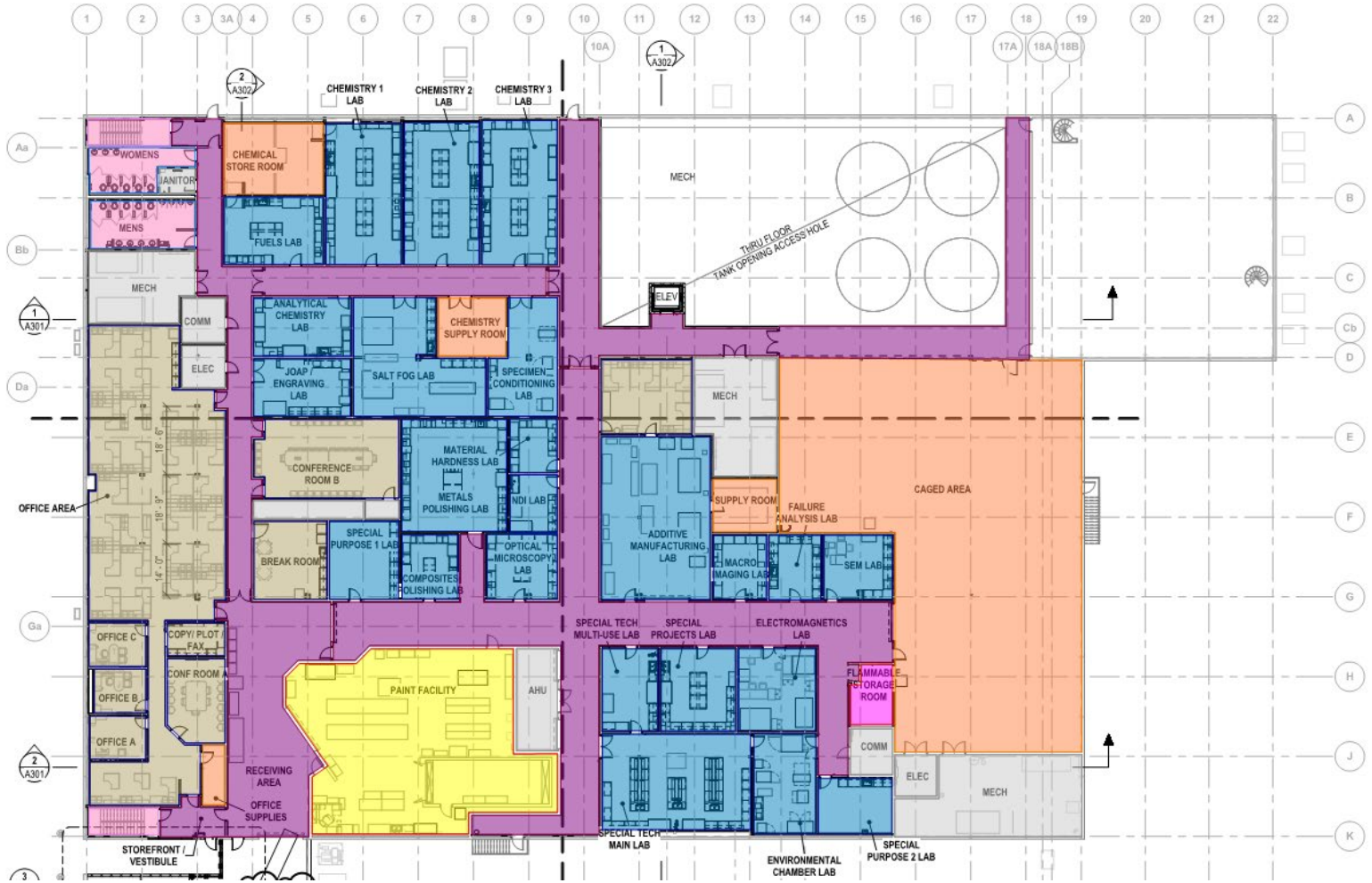
First Floor Floorplan



Legend

- Office
- Service Spaces
- Storage S-2 Low Hazard Storage
- Laboratory
- Exit Access Corridors
- Restrooms
- High Hazard H-2
- High Hazard H-3

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Building Construction

- Type IIB
  - Steel beams
  - Steel roof structure
  - Concrete slabs
  - Concrete foundations
  - Steel-framed/CMU interior walls
  - Brick & steel exterior walls
- Finishes

TABLE 601 FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Primary structural frame[f] (see Section 202)	3[a, b]	2[a, b]	1[b]	0	1[b]	0	HT	1[b]	0
Bearing walls Exterior[e, f] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	2 1/HT	1 1	0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[d]	0	0	0	0	0	0	See Section 2304.11.2	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	$1\frac{1}{2}$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members in roof construction shall not be required, including protection of primary structural frame members, roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

c. In all occupancies, heavy timber complying with Section 2304.11 shall be allowed where a 1-hour or less fire-resistance rating is required.

d. Not less than the fire-resistance rating required by other sections of this code.

e. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

f. Not less than the fire-resistance rating as referenced in Section 704.10.

Allowable Areas, Stories, & Height

- Height: 51’-6”; IBC Table 504.3
- Stories: 2; IBC Table 504.4
- Accessory Occupancies

Accessory Occupancies

Floor	Floor Area (ft^2)	Occupancy	Occupancy Area (ft^2)	Percent of Area
First Floor	44,671	H-2	2,898	6.48%
First Floor	44,671	H-3	811	1.64%
First Floor	44,671	A-3	817	1.83%
First Floor Total				9.95%

Allowable Areas Summary

Occupancy	Allowable Area (ft^2)	Frontage Increase (ft^2)	Modified Allowable Area (ft^2) $A_a = [A_t + (NS \times I_f)]$	Actual Occupancy Area (ft^2)	Ratio to Allowable
B – First Floor	92,000	17,250	109,250	34,617	0.317
S-2 – First Floor	104,000	19,500	123,500	8,071	0.065
First Floor Total				44,671	0.382
F-1 - Basement	62,000	11,625	73,625	7,785	0.106
B -Basement	92,000	17,250	109,250	42,190	0.386
S-2 – Basement	104,000	19,500	123,500	1,587	0.013
Basement Total				51,562	0.505

Egress Systems

- Egress Capacity
  - 36” & 72” doors only
- Exit Arrangement
- Horizontal Exits & Corridors

	Calculated Occupant Load	Egress Capacity	Exits
First Floor	254 People	866 People	Four direct doors, two 44” stairs
Basement	226 People	473 People	One direct door, two 44” stairs
Total Building	480 People	1193 People	Five direct doors, two 44” stairs

	Maximum Diagonal	Distance Between Exits	Compliant?
First Floor	333’-3”	216’-9”	Yes
Basement	333’-3”	179’-9”	Yes
Conf. Room B	42’-4”	14’-3”	No
Shop	170’-1”	150’-7”	Yes
Utility Floor	237’-1”	139’-11”	Yes

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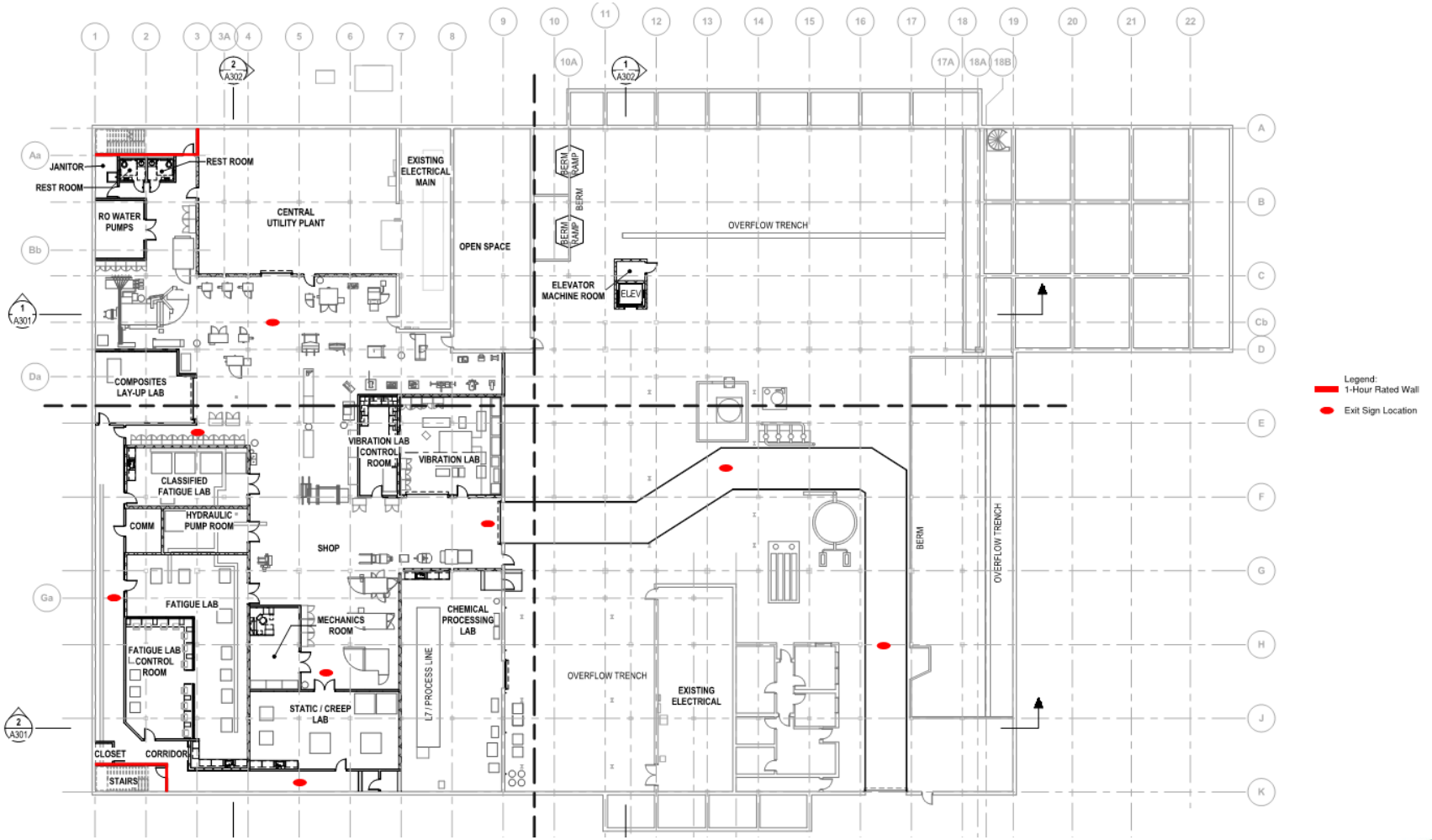
Basement Fire Separation & Exit Signs



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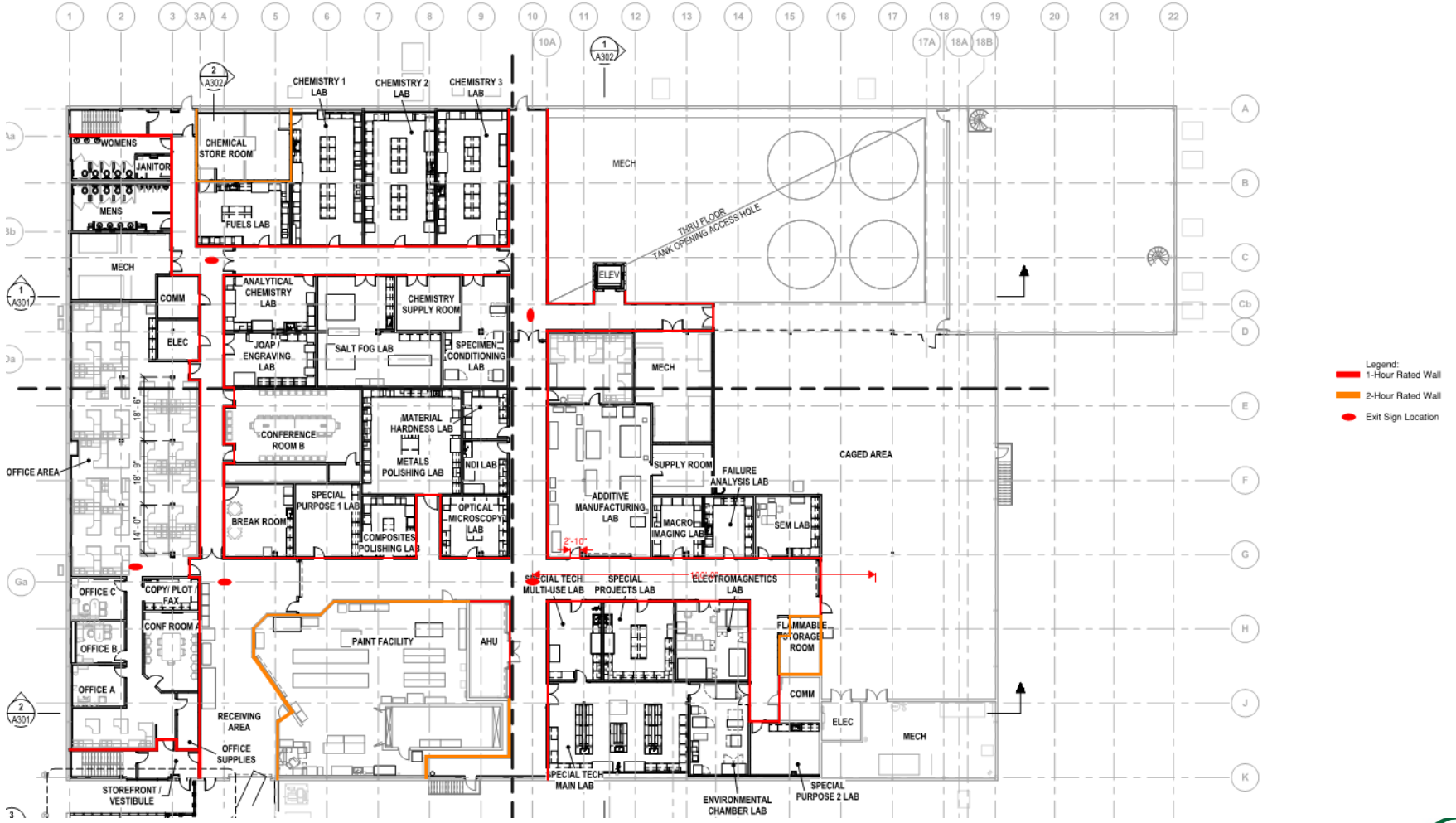
First Floor Fire Separation & Exit Signs



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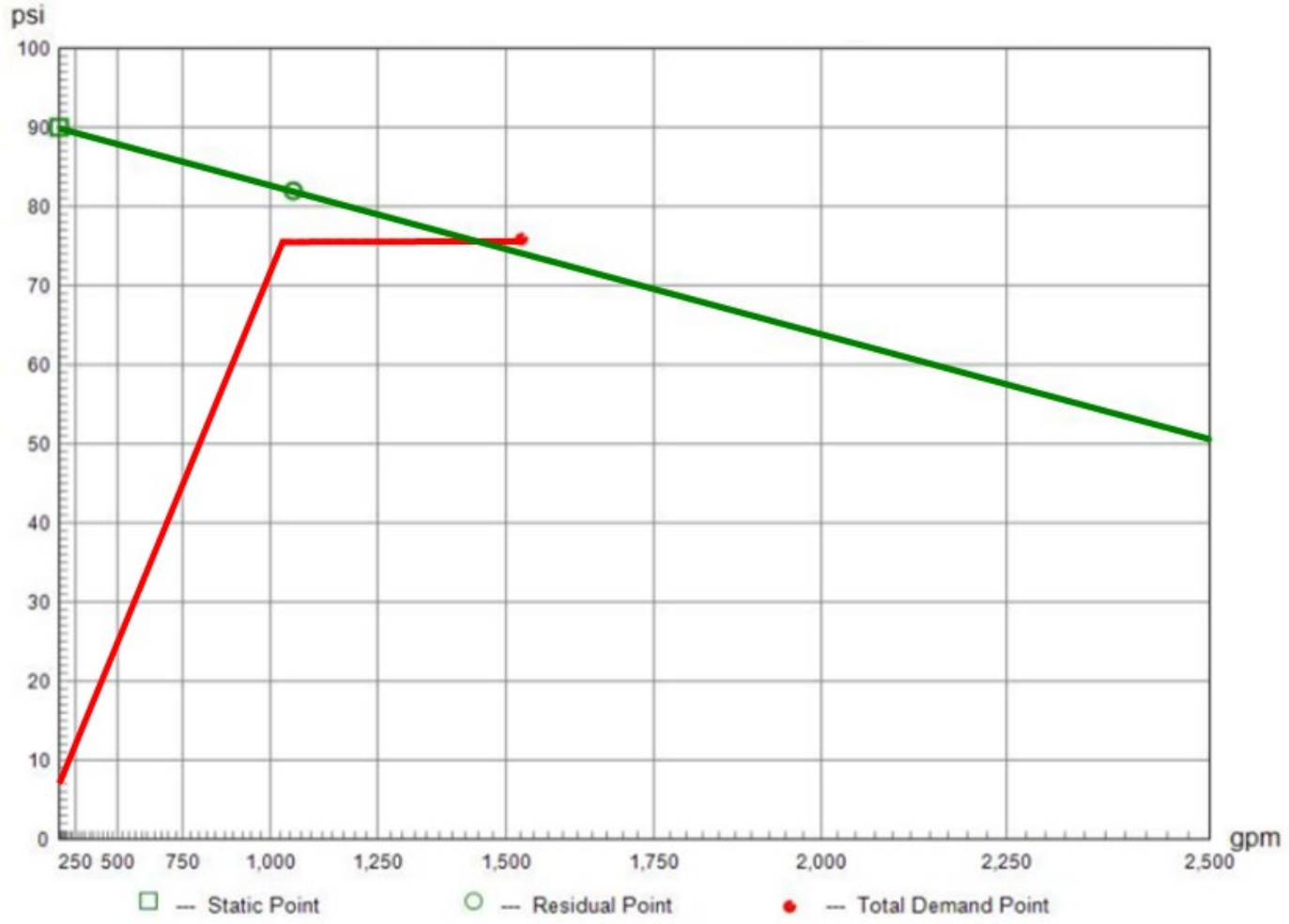
Fire Suppression Systems

- 2 wet-pipe systems
- 1 dry-pipe system
- FM Global & UFC guided
- Seismic Bracing

Hazard Classification	Remote Area (ft^2)	Density (GPM/ ft^2)	Maximum Area per Sprinkler (ft^2)	Hose Demand (GPM)
Light Hazard	1500	0.10	225	250
Ordinary Hazard	2500	0.20	130	250
Extra Hazard Group I	2500	0.30	100	500
Extra Hazard Group II	2500	0.40	100	500

Hydraulic Design – Chemical Process Lab



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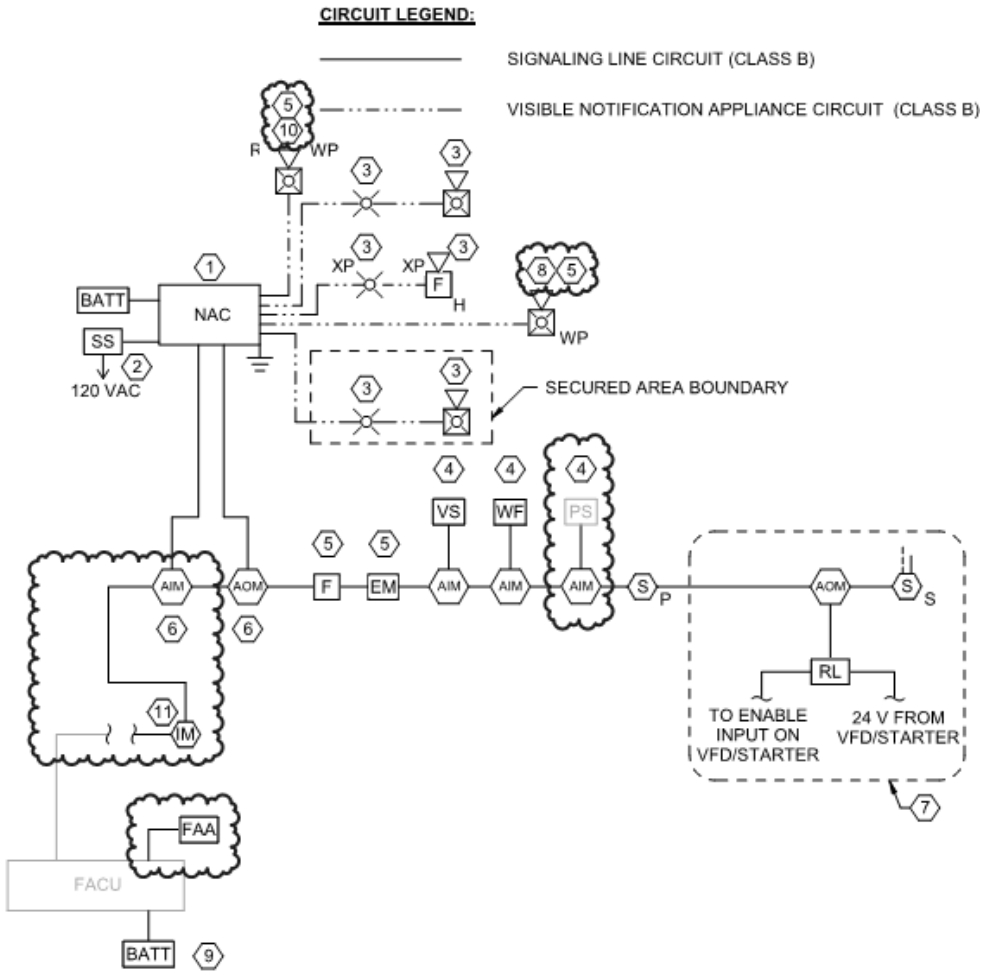
Fire Alarm System

- Sprinkler-led
- Initiating devices
  - Smoke detectors
  - Pull stations
  - Elevator flow
- FACU / Annunciator
- Notification devices

FIRE ALARM CONTROL UNIT (FACU) FUNCTIONAL MATRIX														
	ANNUNCIATION AT LOCAL PANEL			NOTIFICATION				AUXILIARY FUNCTION						
ALARM CONDITIONS	AUDIO-VISIBLE FIRE ALARM INDICATION BY DEVICE	AUDIO-VISIBLE TROUBLE INDICATION BY DEVICE	AUDIO-VISIBLE SUPERVISORY INDICATION BY DEVICE	FIRE ALARM SIGNAL TO FIRE DEPARTMENT	COMMON ALARM SIGNAL TO FIRE DEPARTMENT	COMMON SUPERVISORY SIGNAL TO FIRE DEPARTMENT	FIRE ALARM AUDIBLE/VISIBLE NOTIFICATION	SHUT-DOWN ASSOCIATED AIR HANDLING EQUIPMENT	ACTIVATE ASSOCIATED HORN/STROBES OVER FDC	INITIATE ELEVATOR SHUNT TRIP	RETURN ELEVATOR TO BASEMENT FLOOR	RETURN ELEVATOR TO FIRST FLOOR	ACTIVATE EXTERIOR RED-LENS HORN STROBES	
MANUAL FIRE ALARM STATIONS	X			X			X						X	
EMERGENCY PULL STATIONS	X			X			X						X	
WATERFLOW SWITCH-WET PIPE SYSTEM	X			X			X		X					
WATERFLOW SWITCH-ELEVATOR MACHINE ROOM	X			X			X			X				
SMOKE DETECTOR ELEVATOR MACHINE ROOM	X			X			X			X				
HEAT DETECTOR ELEVATOR MACHINE ROOM	X			X			X			X				
HEAT DETECTOR ELEVATOR BOTTOM OF SHAFT	X			X			X					X		
SMOKE DETECTOR BASEMENT	X			X			X					X		
SMOKE DETECTOR FIRST FLOOR	X			X			X				X			
TROUBLE CONDITIONS														
AC POWER FAILURE		X			X									
LOW BATTERY		X			X									
OPEN CIRCUIT FAULT		X			X									
GROUND FAULT		X			X									
NOTIFICATION APPLIANCE CIRCUIT SHORT		X			X									
SUPERVISORY CONDITIONS														
DEACTIVATION FOR MAINTENANCE			X			X								
IN-DUCT SMOKE DETECTORS			X			X			X					
GENERAL VALUE SUPERVISORY			X			X								

One-Line Diagram



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Secondary Power

Circuit	Panel	Horn Strobe 15cd @ 73mA	Horn Strobe 30cd @ 90mA	Horn Strobe 75cd @ 139mA	Horn Strobe 95cd @ 160mA	Horn Strobe 115cd @ 182mA	Horn Strobe 135cd @ 211mA	Horn Strobe 185cd @ 262mA	Strobe 15cd @ 43mA	Strobe 30cd@ 63mA	Strobe 75cd@ 107mA	Strobe 185cd@ 222mA	Wire Size (AWG)	Resistance (Ohms/1000')	Total Length (ft)	Total Current (Amps)	Voltage Drop
NAC B-1	FACP		1	1				2	2	2	1		12	1.98	865	1.072	1.8360144
NAC B-2	FACP	1	2	2	1		1		2	1	2		12	1.98	815	1.265	2.0413305
NAC B-3	FACP	4	1	5					1				12	1.98	875	1.12	1.9404
NAC B-4	FACP		1	6	1				1		1		12	1.98	845	1.234	2.0646054
NAC B-5	FACP		1	4	2						1		12	1.98	1030	1.073	2.1882762
NAC B-6	FACP			1				3				1	12	1.98	780	1.147	1.7714268
NAC B-7	FACP	3		2			1		4				12	1.98	1135	0.88	1.977624
NAC 1-1	FACP	3		2		1	1						12	1.98	720	0.89	1.268784
NAC 1-2	FACP	1	3			2			1	4			12	1.98	820	1.002	1.6268472
NAC 1-3	FACP	5	2	2					2		1		12	1.98	1170	1.016	2.3536656
NAC 1-4	FACP	3		5					4				12	1.98	1130	1.086	2.4298164
NAC 1-5	FACP	7		3					1				12	1.98	1055	0.971	2.0283219
NAC 1-6	FACP	2	4	3							1		12	1.98	995	1.03	2.029203
NAC 1-7	FACP	2		4					2				12	1.98	820	0.788	1.2793968
NAC 1-8	FACP	3	2	2					4	1			12	1.98	1165	0.912	2.1037104
NAC 1-9	FACP					3							12	1.98	815	0.546	0.8810802
NAC 1-10	FACP					3							12	1.98	685	0.546	0.7405398
NAC 1-11	FACP								1				12	1.98	250	0.043	0.021285
NAC 1-12	FACP									1			12	1.98	85	0.063	0.0106029
NAC 1-13	FACP									1			12	1.98	400	0.063	0.049896
NAC 1-14	FACP			1									12	1.98	420	0.139	0.1155924
NAC 1-15	FACP			1									12	1.98	285	0.139	0.0784377
NAC 1-16	FACP			1									12	1.98	195	0.139	0.0536679

Equipment			Supervisory Current (Amps)		Alarm Current (Amps)	
Tag/Type	Part Number	Quantity	Unit	Total	Unit	Total
SLC B-1		1			1.072	1.072
SLC B-2		1			1.265	1.265
SLC B-3		1			1.12	1.12
SLC B-4		1			1.234	1.234
SLC B-5		1			1.073	1.073
SLC B-6		1			1.147	1.147
SLC B-7		1			0.88	0.88
SLC 1-1		1			0.89	0.89
SLC 1-2		1			1.002	1.002
SLC 1-3		1			1.016	1.016
SLC 1-4		1			1.086	1.086
SLC 1-5		1			0.971	0.971
SLC 1-6		1			1.03	1.03
SLC 1-7		1			0.788	0.788
SLC 1-8		1			0.912	0.912
SLC 1-9		1			0.546	0.546
SLC 1-10		1			0.546	0.546
SLC 1-11		1			0.043	0.043
SLC 1-12		1			0.063	0.063
SLC 1-13		1			0.063	0.063
SLC 1-14		1			0.139	0.139
SLC 1-15		1			0.139	0.139
SLC 1-16		1			0.139	0.139
FACP	ACM-24AT	1	0.23	0.23	0.23	0.23
Remote Annunciator	LCD-160	1	0.3	0.3	0.325	0.325
Duct Detector	TC806DNR	14	0.0003	0.0042	0.012	0.168
135 °F Heat Detector	TC808B1041	1	0.0003	0.0003	0.0065	0.0065
190°F Heat Detector	TC808B1066	2	0.0003	0.0006	0.0065	0.013
Manual Pull Station	S464G1007	11	0.000375	0.004125	0.005	0.055
Photoelectric Detector	TC806B1076	12	0.0003	0.0036	0.0065	0.078
Tamper Switch	FDM-1	14	0.0008	0.0112	0.0008	0.0112
Waterflow Switch	FMM-1	4	0.0003	0.0012	0.0003	0.0012
Monitor Module	TC809A1059	40	0.000375	0.015	0.005	0.2
		Total Current:		0.570225		18.2519
		Hours:		24		0.084
		Amphour subtotal:		13.6854		1.53316
		System Amphours:		15.21856		
		Derating Factor:		0.2		
		Total Amphours:		18.26227		
		Batteries Provided:		2x 26AH		
		Spare Capacity:		33.73773		

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Prescriptive Review

- Construction – Acceptable to IBC
- Egress – Minor Issue in Single Space
- Fire Suppression – Not acceptable
  - Approved by AHJ
- Fire Alarm – More than acceptable

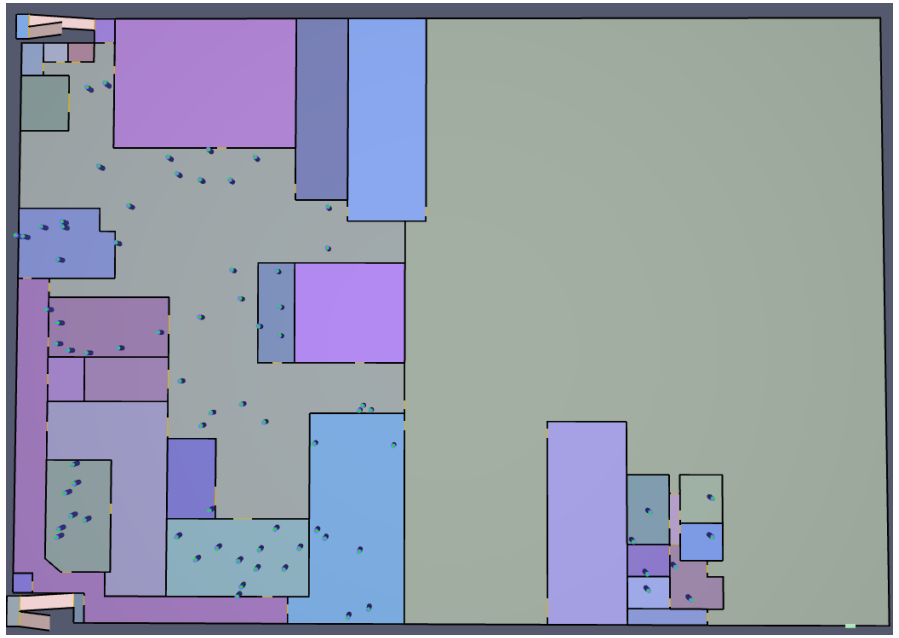
Performance Based Design - Objectives

- Objective: Life safety of nonlocal occupants
  - Hostile environment
  - Maintain Egress Capacity
  - Structural Integrity
- ASET vs RSET

Metric	Value	Location
Breathing Zone Temperature	60°C	6’ Above Floor
Egress Hall Visibility	4 m	6’ Above Floor
Steel Structure Temperature	600°C	Any steel structure

RSET Development

- Modeled in Pathfinder
  - Unoccupied spaces empty
  - Random assignment within rooms
  - Total load: 322 people
- Occupant Characteristics
  - Delay to move by space type
  - Move direct to nearest exit
  - 4 ft/s
  - 18” diameter



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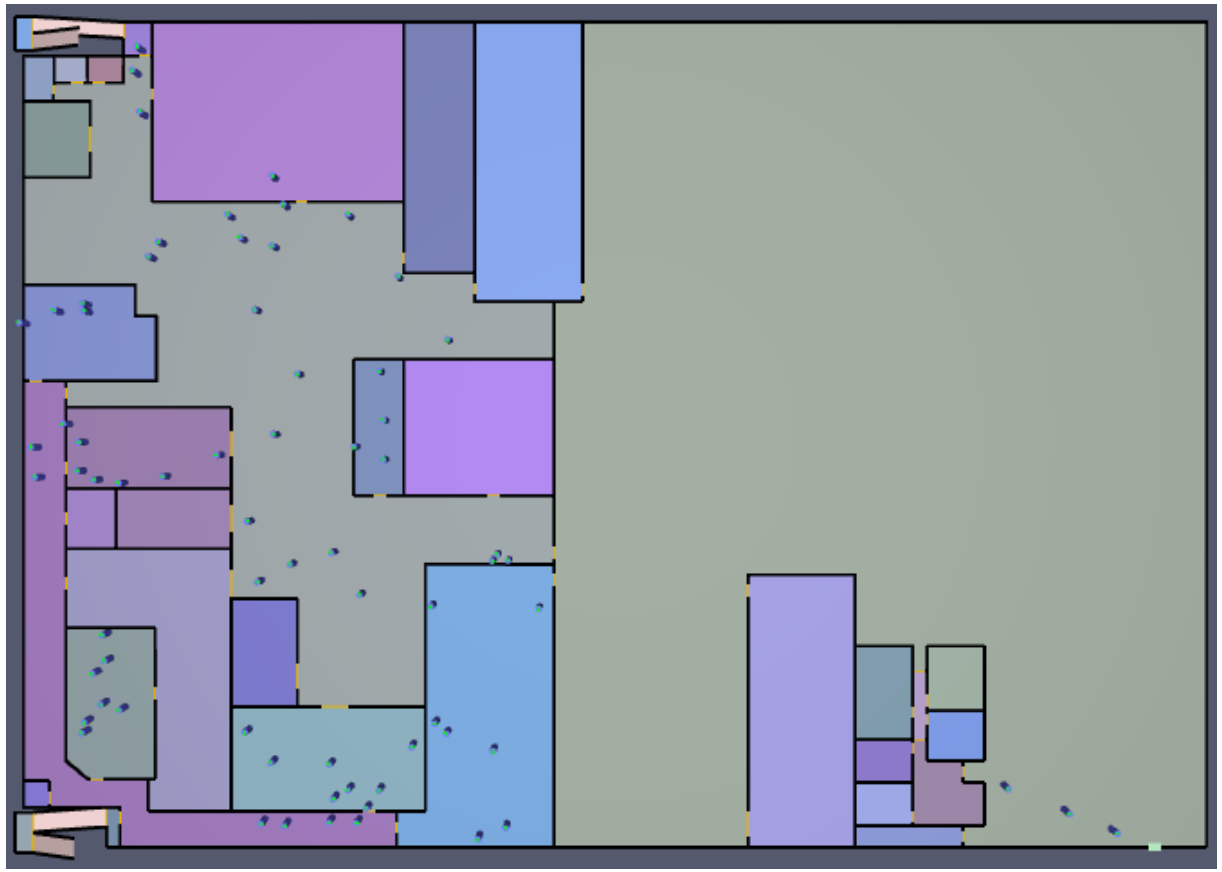
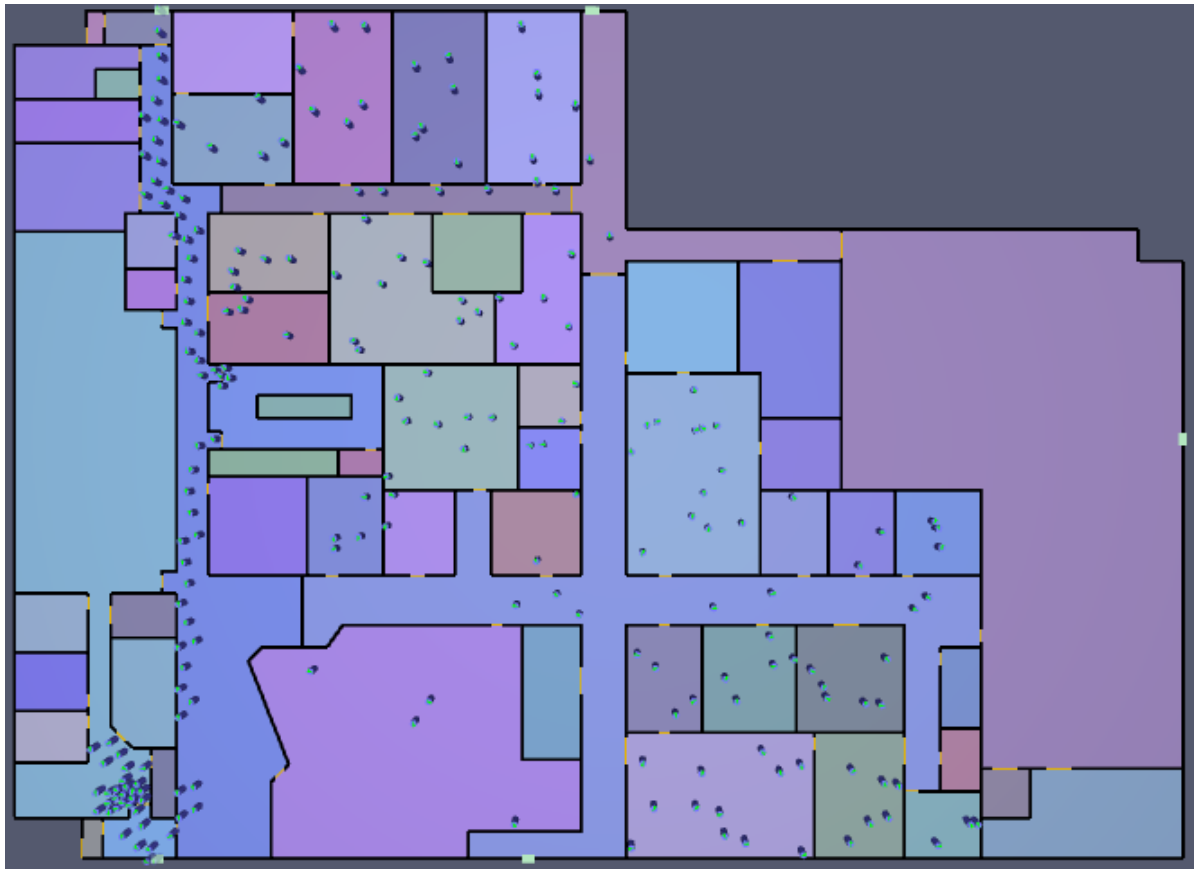
Egress Start - 30 Seconds





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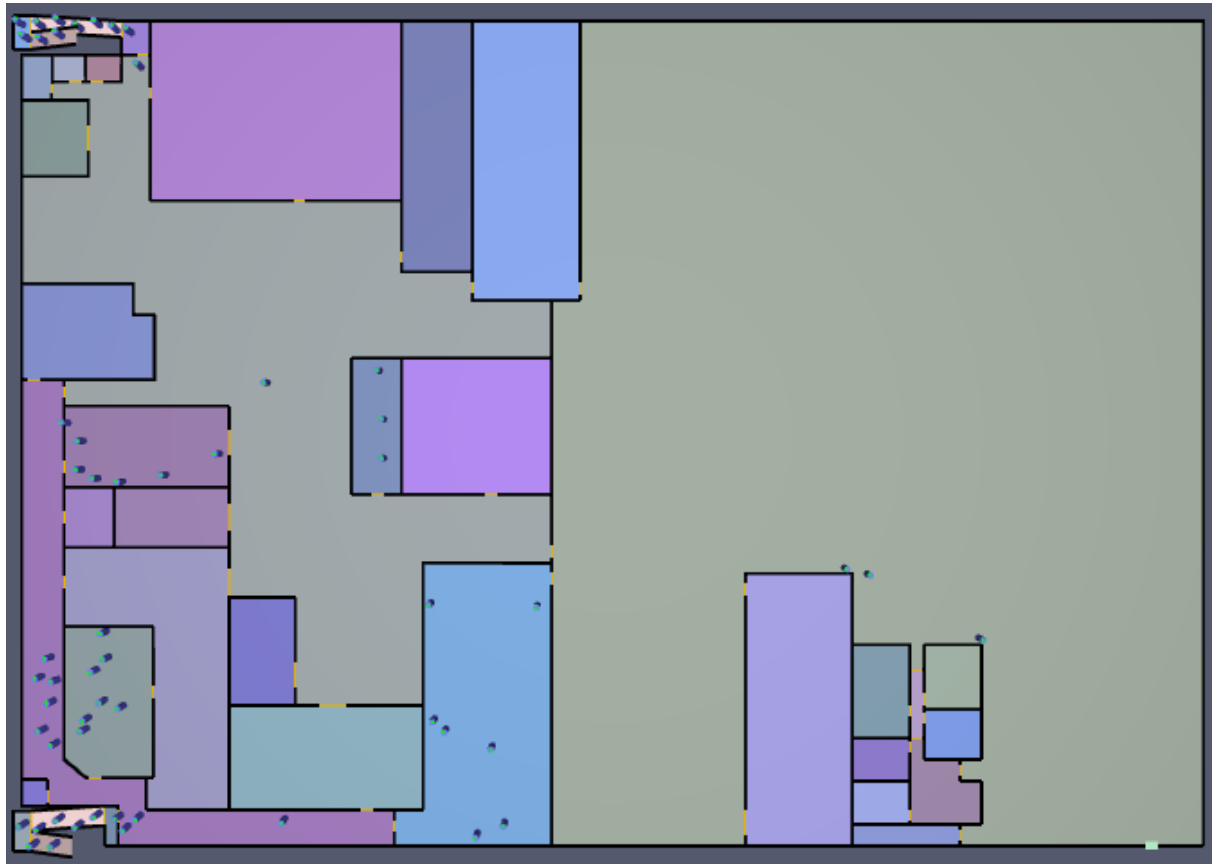
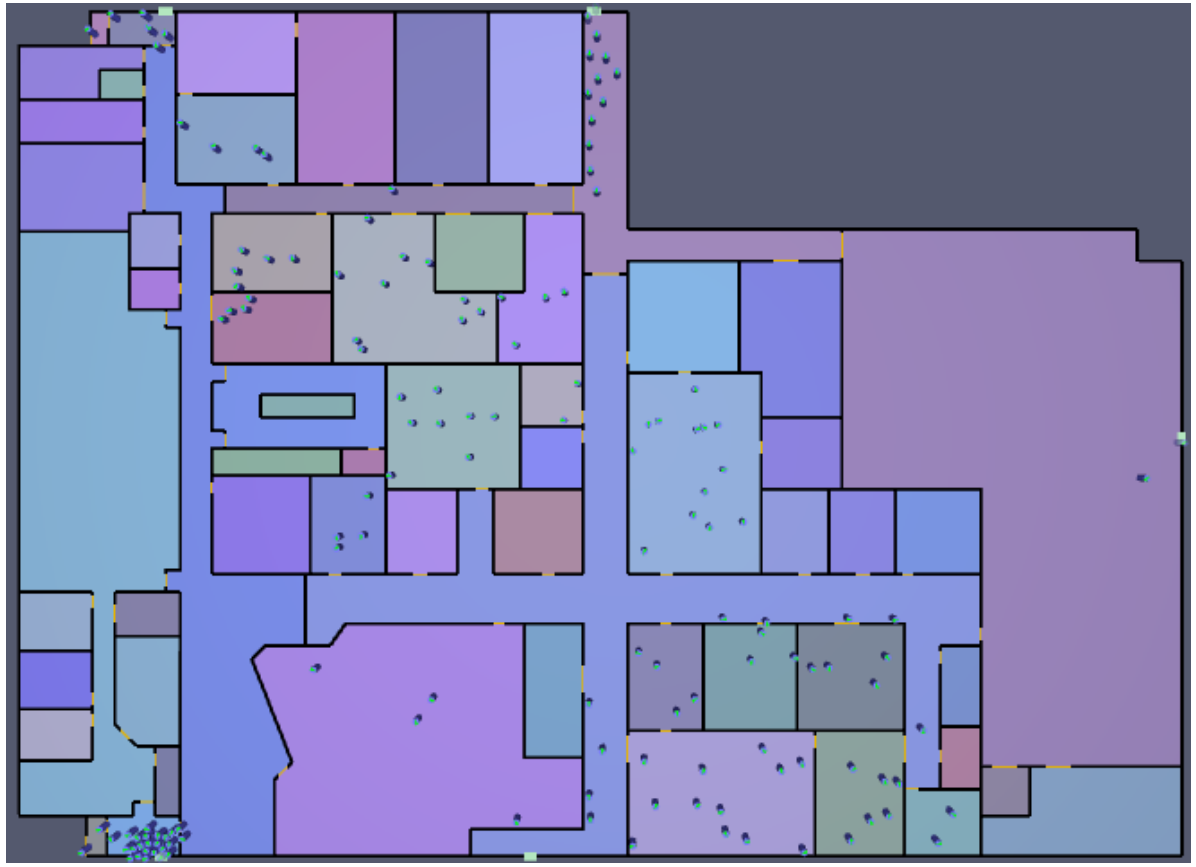
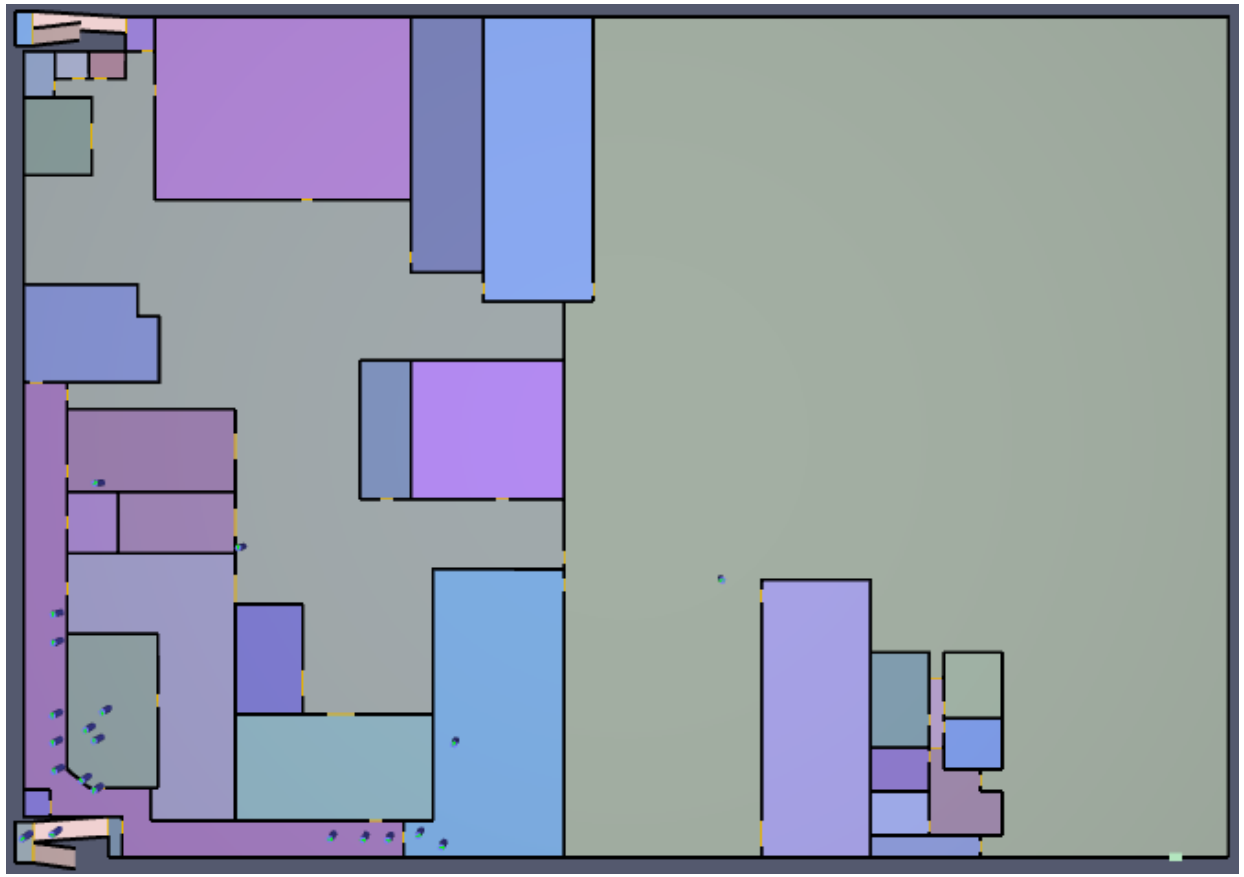
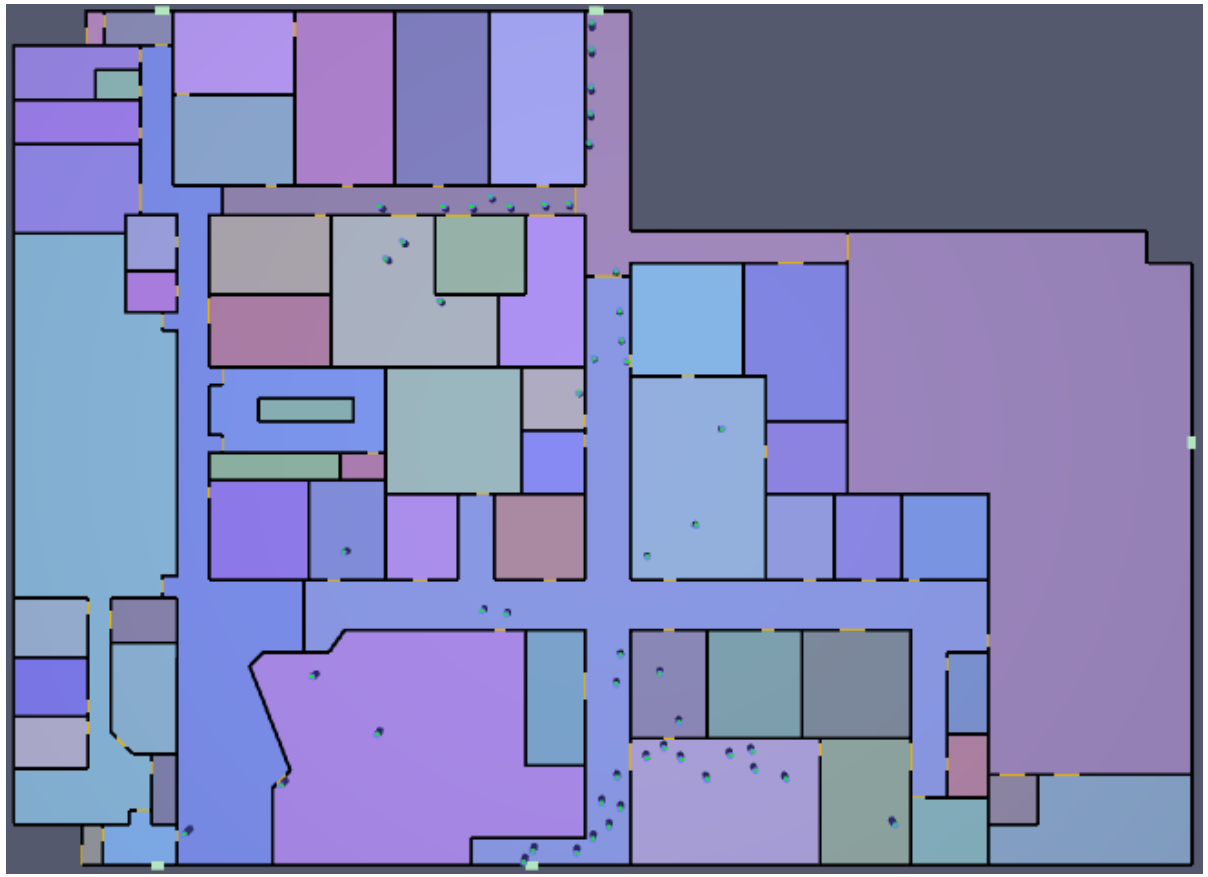
Crowding – 60 Seconds





Stragglers Start– 130 Seconds





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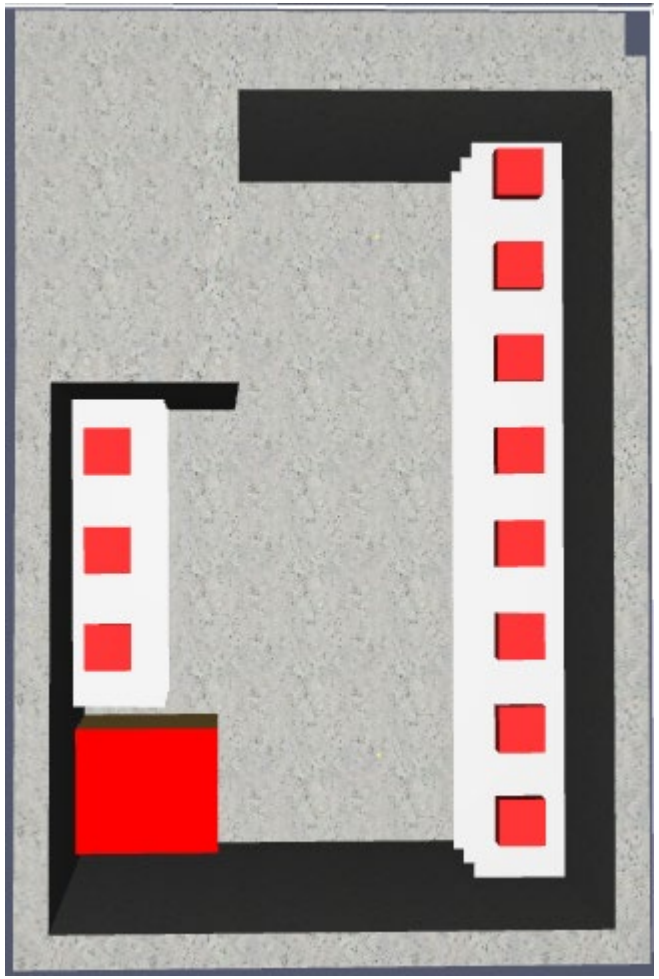
Design Fire 1 – Flammable Storage Room

- Burner: 40 gal Ethyl Alcohol tank
- Additional Fuel: 2 gallon tanks of Jet-A on steel racks
- 1-hour rated CMU walls
- 6-in poured concrete slab
  - Steel reinforcement 4-in deep



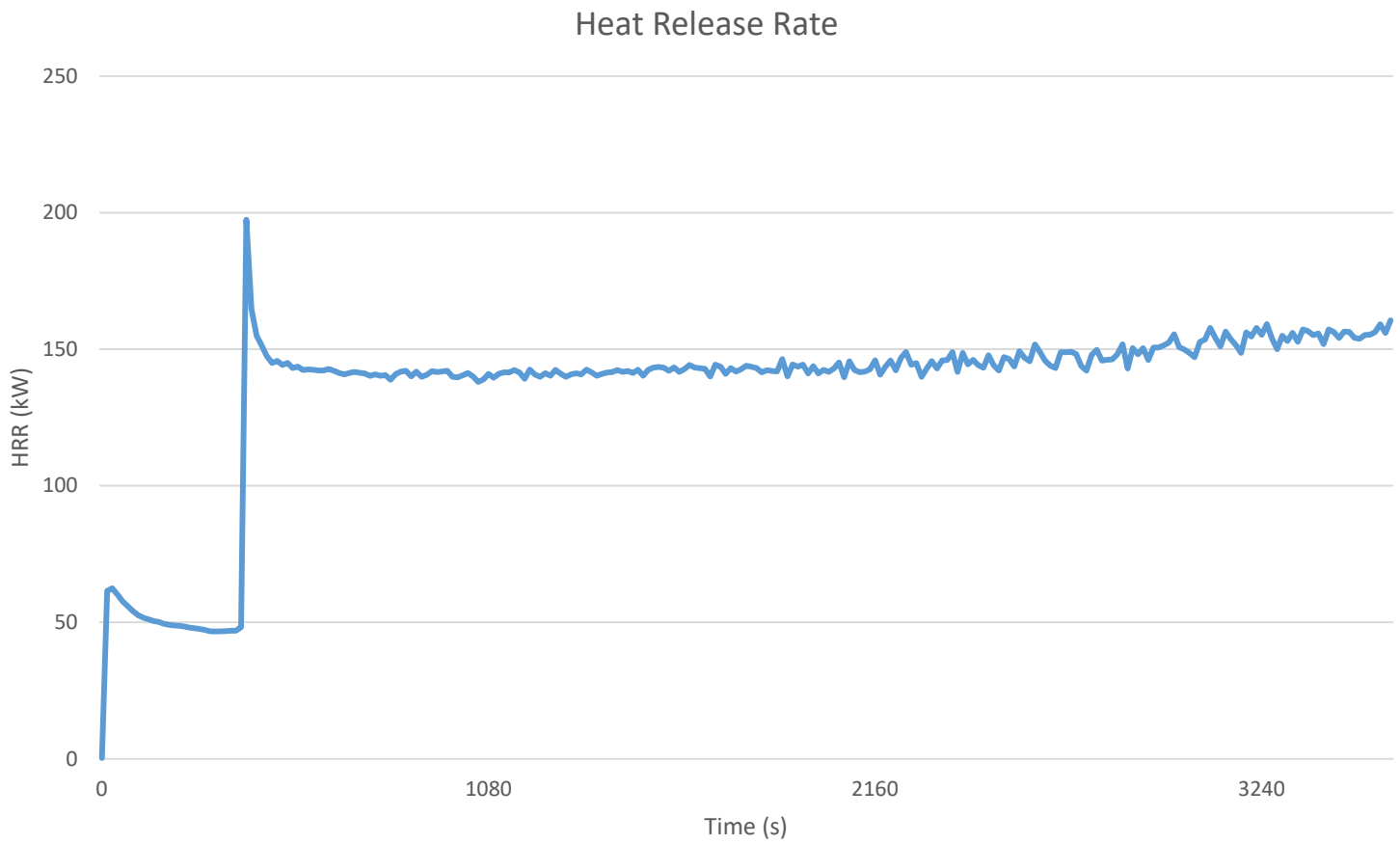
Top View

Design Fire Inputs

Fuel	Formula	Heat of Combustion (kJ/g)	Ignition Temperature (°C)	Specific Heat (kJ/kg*K)	Density (kg/m^3)	Conductivity (W/mK)
Ethyl Alcohol	C2H6O	29.67	362	1.33	790	0.171
Jet-A (in PE)	C15H32	43.3	220	2.01	500	0.145

Material	Density (kg/m^3)	Specific Heat (kJ/kg*K)
Concrete	2002.3	0.911
Steel	7870	0.489

Heat Release Rate



$$\dot{Q} = (A * \dot{y} * \rho)\Delta h_c$$

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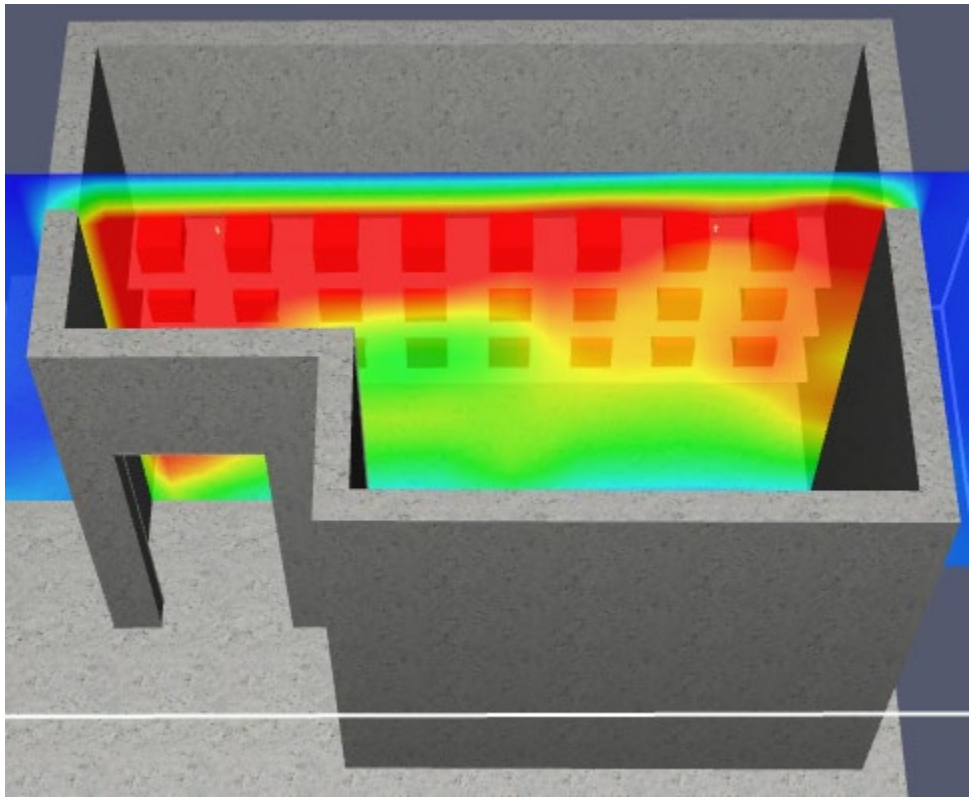
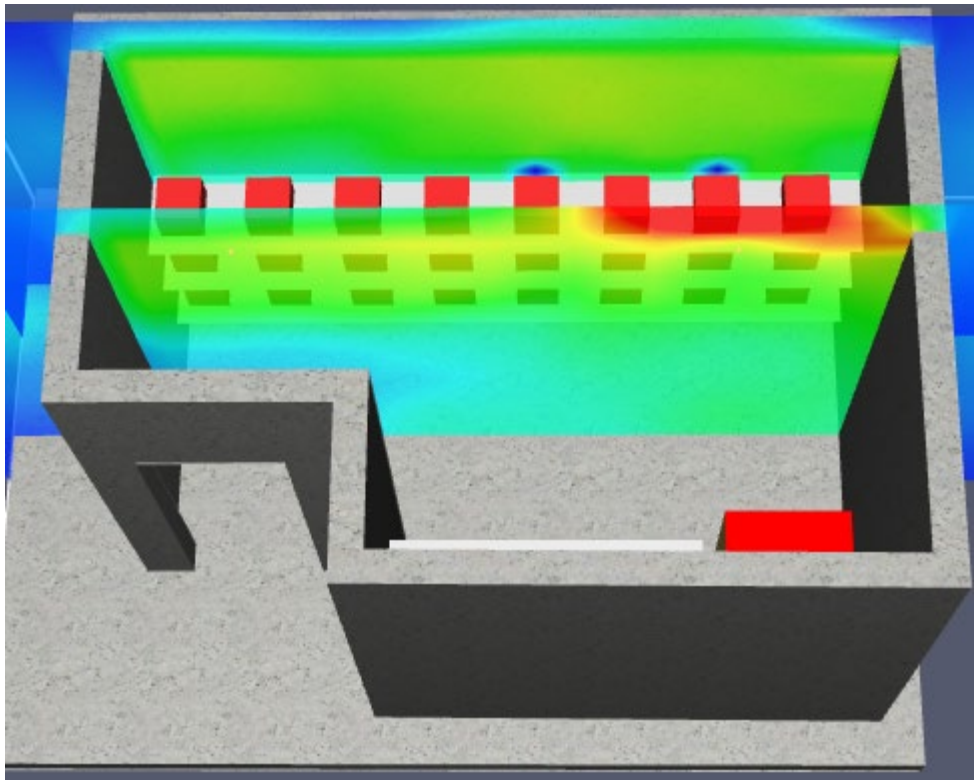
Design Fire Analysis

- Model Run: 4 hours
- Devices
  - Sprinkler at 386.5 s
  - No heat detectors activate at any point.
- Peak smoke discharge: 156 cfm
  - Open corridor: 43,000 ft^3

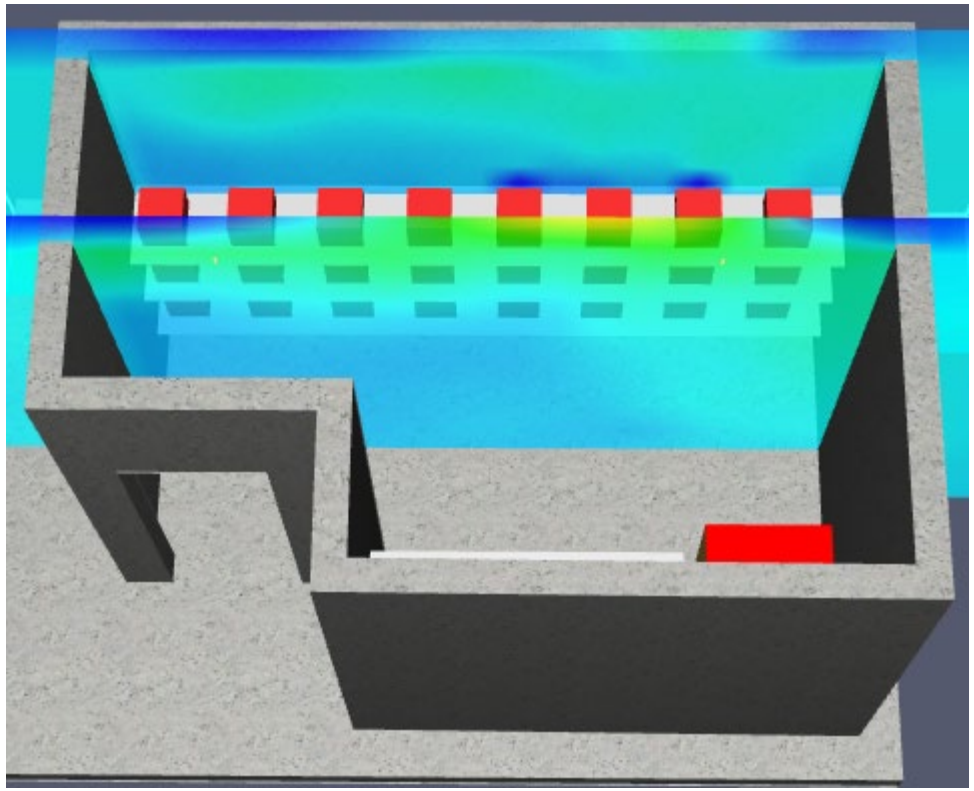


386.5 Seconds

Design Fire Analysis cont.



1 Hour



2.5 Hours

Risk Assessment

- Extremely unlikely ignition
  - Alcohol must be left unsealed
  - Sparked ignition source must be provided
- Consequence is Low
  - Successful performance of fire suppression
  - Minimal damage other than fuel consumption and smoke

Frequency ▶ / Consequence ▼	Beyond extremely unlikely $f \leq 10^{-6}\text{yr}^{-1}$	Extremely unlikely $10^{-4} \geq f > 10^{-5}\text{yr}^{-1}$	Unlikely $10^{-2} \geq f > 10^{-4}\text{yr}^{-1}$	Anticipated $f > 10^{-2}\text{yr}^{-1}$
High	10	7	4	1
Moderate		8	5	2
Low		9	6	3
Negligible	11	12		

Key: High Risk; Moderate Risk; Low Risk; Negligible risk

Summary

- Prescriptive
  - Structure and construction are acceptable
  - Minor egress concerns
  - Inadequate water supply, but approved by AHJ
  - More than adequate fire alarm
- Performance
  - Under worst-case fire, fire suppression is key
  - No risk of structural failure
  - Life safety only in danger to those local to the fire

Questions?

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